DEFENCE DÉFENSE

Prediction of Radiological Hazard Areas with HPAC

D.S. Haslip
Defence Research Establishment Ottawa

DEFENCE RESEARCH ESTABLISHMENT OTTAWA

TECHNICAL MEMORANDUM
DREO TM 1999-089
October 1999

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Canada

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Space Systems and Technology Section

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ABSTRACT

The dispersal of radioactive materials in a number of military scenarios has been modelled computationally. This work is part of an international intercomparison of computational capabilities under the auspices of Action Group 44 of The Technical Co-operation Program. The results presented herein were obtained with the Hazard Prediction and Assessment Capability (HPAC), designed by the US Defense Threat Reduction Agency (DTRA). This sophisticated software can be used to quickly determine the extent of radiological hazard areas, requiring a relatively small quantity of information from the user. The potential of this software for applications such as pre-deployment preparation, or even pseudo-real-time hazard prediction with input from hand-held radiation detection equipment must be recognised.

RÉSUMÉ

La diffusion des matériaux radioactifs dans plusieurs scénarios militaires a été modèlé avec un ordinateur. Ces calculs ont été exécutés en tant qu'élément d'une intercomparaison internationale sous les auspices du TTCP AG-44. On a utilisé le logiciel HPAC, conçu par le DTRA, pour faire des calculs. Ce logiciel sophistiqué peut calculer vite les tailles des zones exposés dans ces scénarios radiologiques. Ça, ç'est important pour faire la planification avant d'arriver sur la scène d'un accident.

EXECUTIVE SUMMARY

Document Number: DREO TM 1999-089
Title: Prediction of Radiological Hazard Areas with HPAC (U)
Author: Dean S. Haslip
Defence Research Establishment Ottawa

Background: Action Group 44 of The Technical Co-operation Program has started an international intercomparison of national capabilities for performing calculations of interest in military-relevant radiological scenarios. Canada has participated in this effort, partly through the work presented in this report.

Results: Hazard prediction calculations have been performed for three TTCP-defined incidents: a radiological dispersal weapon, a low-yield fission weapon, and a nuclear reactor release. The HPAC software used to perform these calculations provides a wealth of hazard information given a minimum of information about the incident. Furthermore, it allows the user to describe the incident to a high degree of precision, should this information be available. A calculation is also presented of the explosive dispersal of an oil-well logging source. This was a scenario of some concern during the Gulf War, and continues to be a realistic hazard world-wide, given the commercial availability of these sources.

Significance: The power of this type of software could be harnessed in a number of military applications. The most obvious is pre-deployment preparation, should the CF consider moving into an area contaminated by a radiological weapon or accident.

Another possibility is the combination of this software with an array of radiological sensors. A bio-chemical version of such a system is under development by DRES, in which an HPAC derivative program is linked to the CIBADS biochemical sentry system. Just as DREO designed the ARDS system as a radiological system to CIBADS, so one could develop a software extension that considers radiological dispersion.

Finally, for radiological hazards, one could envision a system in which the output of man-carried nuclear sensors, such as personal dosimeters or survey meters, is radioed back to a central point employing an HPAC-derivative program. This would be a somewhat more complex and flexible version of the CIBADS-linked system described above.

SOMMAIRE

Numéro de Document: DREO TM 1999-089
Titre: Prévision des Régions de Risque Radiologiques avec HPAC (U)
Auteur: Dean S. Haslip
Centre de Recherche pour la Défense Ottawa

Base de connaissance: Le groupe d'action 44 du programme de co-opération technique (TTCP AG-44), a commencé une comparaison internationale des capacités nationales pour la performance des calculs des intérets pour les scénarios radiologiques de pertinence militaires. Ce document est une partie de la participation du Canada dans ce travail.

Résultats: Les calculs de prédictions de danger ont été fait pour trois incidents TTCP: une arme de dispersion radiologique, une arme de rendement énergétique faible, et la fuite de matières radioactives d'un réacteur nucléaire. Le programme HPAC utilisé pour ces calculs, offre une mine d'information de danger avec le minimum d'information disponible à propos de l'incident. En plus, ceci permet à l'utilisateur de décrire l'incident à un tres haut niveau de précision si cette information est disponible. Un calcul est aussi présenté sur une explosion de mine d'huile. Ceci etait un intéret special durant la guerre du golfe, et continue d'être un danger réel à travers le monde en étant donné la disponibilité commerciale de cette source.

Signification: Le pouvoir de ce type de program pourrait etre utilisé dans plusieurs applications militaires. La plus evidente est la préparation de pre-déploiement si les Forces Canadiennes considerait entrer dans une zone contaminée de radioactivitée ou un accident nucléaire.

Une autre possibilitée est le rapprochement de ce program avec les avant postes de sondage radiologique. Une configuration bio-chimique de ce program est sous développement par CRDS, une dérivée du program HPAC est liée au systeme sentinel bio-chimique CIBADS. Juste comme CRDO a conçu le systeme ARDS comme un systeme radiologique à CIBADS, quelqu'un pourrait développer un extension du programme qui considere la dispersion radiologique.

Finallement, pour les dangers radiologiques, on pourrait envisionner un systeme auquel les résultats de débit des détecteurs nucléaire portatifs, comme les dosimetres personnels et les instruments de détection, est envoyé par radio à un point central en employant une dérivative du programme HPAC. Ceci serait une version plus complexe et flexible du systeme CIBADS décrit ci-haut.

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1 INTRODUCTION

The nature of the nuclear threat to the Canadian Forces (CF) has changed. The likelihood of large-scale nuclear weapons exchange has been reduced since the end of the Cold War. However, there is now heightened concern over a number of smaller-scale nuclear or radiological scenarios. These include:

(1) Radiological Dispersal Weapon (RDW) – an exploded radioisotopic source, with the radioactive material coming from any of a number of modern industries that use such products.
(2) Improvised Nuclear Device (IND) – a fission weapon such as might be produced by a so-called "rogue nation" or terrorist.
(3) Sabotaged or Damaged Nuclear Reactor (SDR) – a Chernobyl-like accident occurring by accident or as a result of terrorist activity.
(4) Nuclear Re-Processing Facility – in light of the recent incident in Tokaimura, Japan, a number of accidental or deliberate hazards are now in the spotlight.

DND is taking steps to equip the CF to detect and manage these radiological threats. However, there are still many medical and legal ramifications of conducting operations in a radiologically contaminated environment (such as long-term cancer risks to personnel and the problems of transporting contaminated vehicles and equipment across international borders). As a result, the first principle of radiological operations, especially during Operations Other Than War (OOTW), may be avoidance of the hazard. This requires an accurate prediction of the extent and time evolution of a developing incident. In fact, even if hazard avoidance cannot be accomplished, operations planning could be far more effective if commanders could predict the extent and nature of the hazard to which their forces were about to be exposed.

A number of software tools have been developed that can predict the extent of a radiological hazard as a function of time, given the nature of the incident, meteorological conditions and local terrain. As part of its participation in The Technical Co-operation Panel, Action Group 44 (TTCP AG-44), DREO is involved in a comparison of American, British, and Canadian capabilities in using these tools to predict hazards. This report summarises DREO's results in computing the reference hazards forming the basis of this comparison. It should be noted that this hazard prediction is a new capability for DREO, allowing the DRDB to potentially provide more operational support to the CF.

Section 2 describes briefly the software used to peform these calculations. Section 3 presents the results of the calculations. Section 4 is not part of the TTCP intercomparison, but demonstrates how this new DREO capability may be applied to a radiological hazard that was once of concern for the CF. Section 5 is a further demonstration of the usefulness of this software, showing a hazard assessment produced in half an hour of the recent Tokaimura accident. Section 6 presents some Conclusions and Recommendations related to this work.

2 HAZARD PREDICTION SOFTWARE

For these calculations, DREO has used the Hazard Prediction and Assessment Capability (HPAC), version 3.0 [1]. This code was developed by the US Defense Special Weapons Agency (DSWA), now called the Defense Threat Reduction Agency (DTRA). HPAC takes a user description of the incident (called the "source term"), meteorological data, and terrain data, and uses the SCIPUFF (Second-order Closure Integrated PUFF) [2] transport model to predict where the hazardous material travels as a function of time. The source term generator is capable of handling a variety of Nuclear, Biological, and Chemical incidents.

3 RESULTS OF CALCULATION

3.1 Radiological Dispersal Weapon

3.1.1 Incident Description

This is the simplest of the incidents considered by the Action Group. The source of the hazard is a 10000-Curie source of ^{137}Cs, dispersed by the detonation of fifty kilograms of high explosive at one metre above the ground. The incident description also includes a plume size and particle size distribution. The explosion is sited at a latitude of 34.112768 degrees North and a longitude of 117.532753 degrees West, which is in the Los Angeles Basin. Winds are from ten degrees north of west, at 5 m/s. There is no variation of wind speed or direction with altitude.

This type of incident is readily simulated in HPAC. A relatively simple user interface allows the scenario to be defined by specifying the parameters given above in a series of menus. However, HPAC does not permit control over the particle size distribution or the plume size. The plume size is presumably set by the quantity of explosive; the particle size distribution, if relevant to this transport model, must be defined similarly or through some default values.

HPAC also requires some additional parameters to be set. These include the surface type (forest, urban, water, etc.), surface moisture (dry, normal, wet), and the cloud cover / precipitation (running the gamut from "clear" to "heavy rain" to "heavy snow"). For these simulations, the default values (surface type: cultivated, surface moisture: normal, cloud cover / precipitation: clear) were used. Finally, HPAC looks for a "calculation radius", defining the distance over which calculations are performed. HPAC does not support arbitarily large calculation radii; if too large a value is chosen, the simulation will not run. For this work, calculation radii of around five hundred miles were chosen.

3.1.2 Hazard Prediction

Two simulations were run in this category. The first assumed that the incident occurred above an infinite, flat plane. The second employed the actual terrain in the Los Angeles basin. The differences between the two are significant.

Figure 1 below shows the total dose contours at twenty-four hours after the incident. The upper panel is the result of the "infinite plane" calculation; the lower panel is the result after taking account of terrain. It is obvious that the presence of terrain in the simulation has a considerable effect on the results. This is particularly true of this scenario since the wind is blowing the contamination into the Rocky Mountains, a very significant terrain feature.

For AG-44, the basis of comparison between the various simulations is simple. At twenty-four hours post-incident, the regions receiving doses of 700 rad, 70 rad, 25 rad, 10 rad, 5 rad, 0.5 rad, 0.05 rad, 0.01 rad, and 0.001 rad are characterised with respect to their area, their extent downwind, and their maximum width perpendicular to the wind direction. In addition, at the maximum downwind distance for each region, the internal committed dose is calculated. These values can be easily compared for each of the simulation tools.

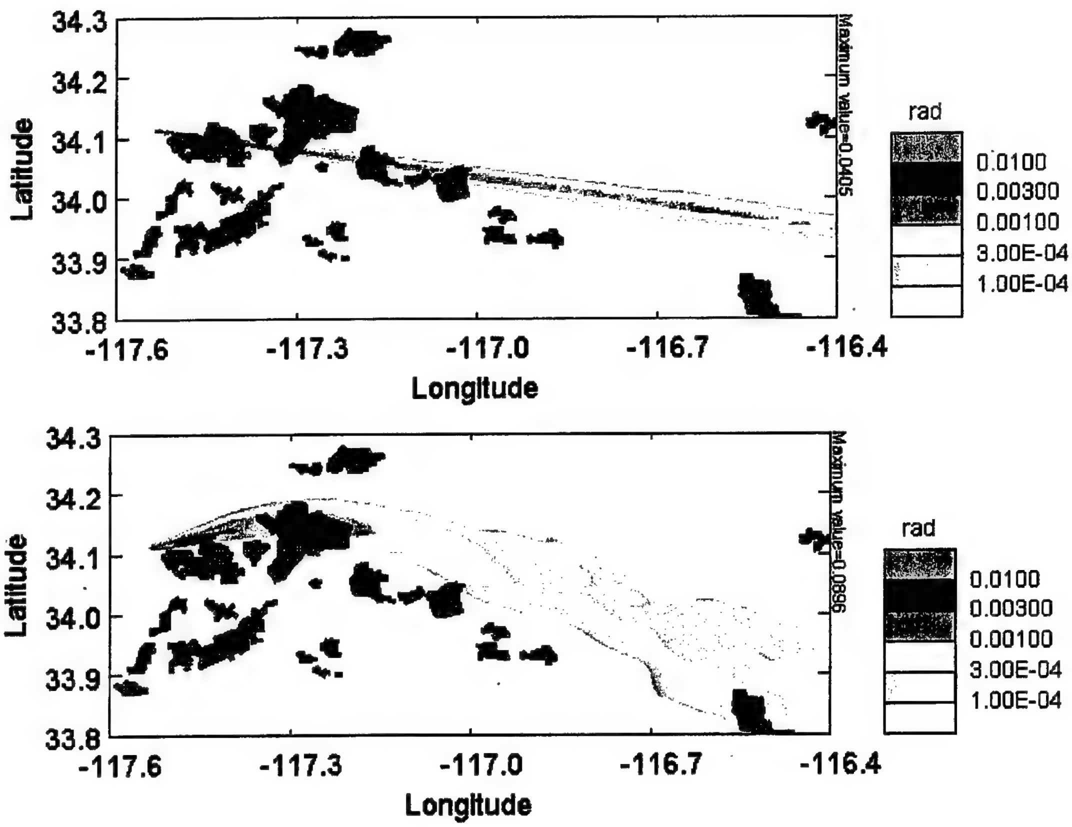

Figure 1: Total dose contours at 24 hours following the explosive dispersal of ten thousand curies of Cesium-137. The lower plot uses the actual terrain in modelling the dispersion; the upper one does not. The darkly shaded areas denote populated places.

Table 1: Area, Maximum Downwind Extent, and Maximum Crosswind Width of regions receiving various doses of gamma radiation.

Dose (rad)	Area (km^2)		Maximum Downwind Distance (km)		Maximum Width (km)	
	No Terrain	Terrain	No Terrain	Terrain	No Terrain	Terrain
0.05		0.052		0.54		0.12
0.01	1.45	1.47	7.77	3.62	0.3	0.52
0.001	109	109	106	34.8	1.32	4.28

Table 2: Internal committed doses and external doses at downwind locations.

External Dose (rad)	Internal 50-year Committed Dose (rem)	
	No Terrain	Terrain
0.05		0.42
0.01	0.086	0.085
0.001	0.0095	0.0091

Table 1 above shows the area, maximum downwind extent, and maximum crosswind width of the regions receiving 0.05 rad, 0.01 rad, and 0.001 rad. Higher doses were not recorded in this simulation. As one might expect from the figure, the downwind distances and the widths are very dependent on the presence of terrain in the simulation. However, the area of these regions is remarkably independent of this factor. This can only be regarded as a coincidence.

Table 2 shows the internal 50-year committed dose at the downwind locations where the external doses are received. The ratio between the internal and external doses is constant, between 8.4 and 9.1, and it is independent of terrain. This is to be expected; the external and internal doses are measures of the extent of contamination, and so should scale together regardless of how the radioactive material disperses. It should be noted that the internal dose calculation must assume a breathing rate. Although the manual for HPAC does not explicitly state this assumption, it is likely that an adult breathing rate of approximately 0.9 m^3/h is used. Military planners often use larger values, between 1.2 m^3/h (light physical exertion) and 2.4 m^3/h (heavy physical exertion). The AG-44 value is 1.5 m^3/h, and the results here likely have to be scaled up to recognise this difference.

It should be noted that the distributions in Figure 1 show only the radiation dose from "groundshine", that is, radiation originating in materials deposited on the ground. HPAC also computes the dose due to "cloudshine", radiation originating in airborne materials. For this scenario, the dose due to cloudshine is negligible compared to the groundshine dose. However, for other scenarios this is not necessarily the case, and it is important to consider both components. Unfortunately, HPAC does not permit the user to add together the two components.

3.2 Improvised Nuclear Device

3.2.1 Incident Description

The Improvised Nuclear Device scenario consists of a single fission weapon. The detonation occurs at ground level, with a yield of twenty kilotons. The yield is due entirely to fission (as opposed to fusion). Ground zero is the same as in the RDW scenario, at 34.112768 North latitude, 117.532753 West longitude. Winds are also taken to be the same as in the RDW scenario.

The simulation of this incident is straight-forward in HPAC. As in the previous scenario, surface type, surface moisture, and cloud cover / precipitation must be specified. Their specification is the same as given above. This scenario does not ask for a calculation radius, however. This can be a problem, as shown below.

3.2.2 Hazard Prediction

As in the previous scenario, simulations were run with and without the effects of terrain taken into account. Figure 2 below shows the dose contours for these simulations. Again, the influence of the Rocky Mountains is evident.

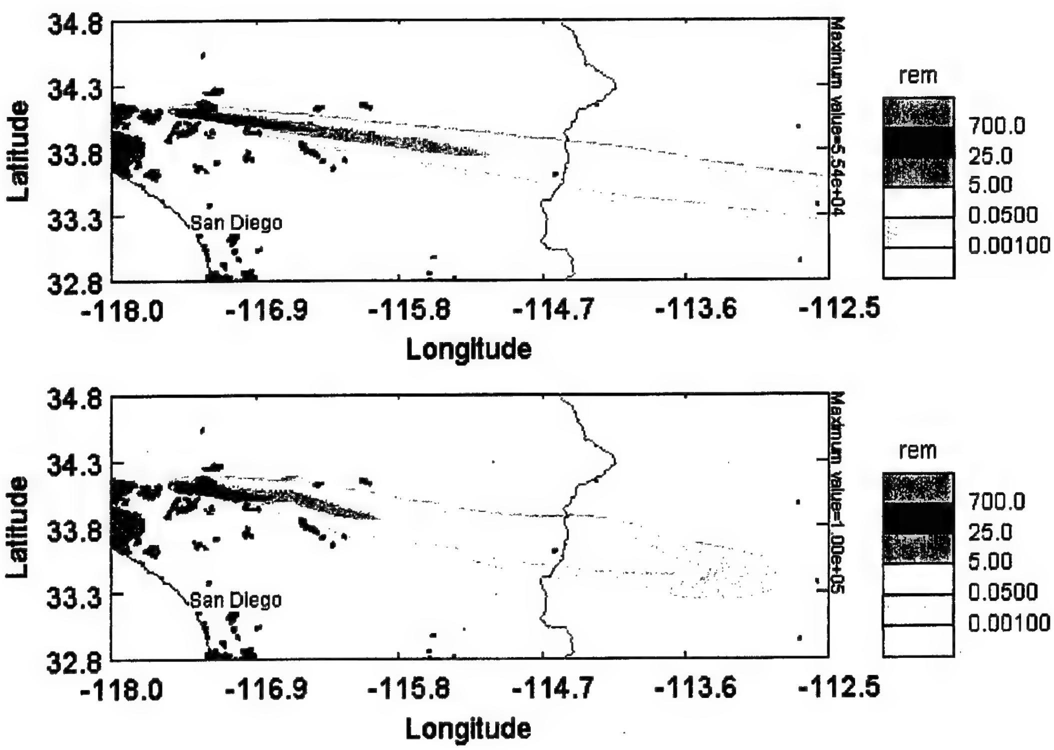

Figure 2: Dose contours for the improvised nuclear device at twenty-four hours post-incident. As before, the upper (lower) panel ignores (includes) the actual terrain in the simulation.

Table 3: Characteristics of areas contaminated by the Improvised Nuclear Device.

Dose (rad)	Area (km^2)		Maximum Downwind Distance (km)		Maximum Width (km)	
	No Terrain	Terrain	No Terrain	Terrain	No Terrain	Terrain
700	34.4	34.1	15.4	11	2.52	3.67
70	293	250	65.4	40.1	6.1	7.54
25	627	546	102	73.4	7.94	9.84
10	1320	987	187	115	9.45	11.6
5	2030	1431	227	150	11.1	14.2
0.5	5600	4030	389	263	20.8	21.6
0.05		9470		385		33.5
0.01		13300		419		43.7
0.001		17700		435		57

As mentioned above, HPAC does not ask for a calculation radius. The calculation radius it selects for itself, however, is not always the most appropriate. In fact, the calculated map cuts off the dose contours as shown in the figure.

Table 3 shows the characteristics of the contaminated areas, as defined in the previous section. As Figure 2 shows, the simulation that includes terrain produces a hazard area that does not extend nearly as far downwind, but that does spread out considerably more in the crosswind direction. As a result, the areas of the hazard areas tend not to depend sensitively on the presence of terrain in the simulation. As discussed in the previous section, this should be viewed primarily as a coincidence.

HPAC employs a different simulation engine to model the IND, as opposed to the RDW. The IND simulator does not calculate internal doses, so this part of the comparison cannot be made.

3.3 Sabotaged or Damaged Nuclear Reactor

3.3.1 Incident Description

The Sabotaged or Damaged Reactor scenario is considerably more complex than the two scenarios considered thus far. The reactor of interest is a PAKS-4 reactor (VVER type), located in Hungary, at 46.572498 North latitude, 18.854166 East longitude. The incident is described as a Steam Generator tube rupture with dry secondary release (release type STC5). To ensure conformity, a release inventory is given. This inventory, which will not be reiterated here, contains 52 isotopes with activities between 10^8 and 10^{18} Becquerels. So-called "multi-level winds" are given; six atmospheric observations are given at altitudes between 28 m and 9500 m. Each observation consists of pressure, wind speed and direction, temperature, and relative humidity. The winds near the surface are from the ENE at approximately 7 m/s, changing to 15 m/s from the ESE at higher altitudes.

The specification of this incident in HPAC is obviously more detailed than in the previous cases. HPAC allows the user to specify release velocities and gas temperatures to permit buoyancy calculations. These parameters were not set. Also, the weather specification required another data point at an altitude below 100 m. An interpolated data point was created for an altitude of 66 m.

3.3.2 Hazard Prediction

Performing this simulation was considerably more difficult than the other two. In order to handle multi-level winds, a different sub-program is activated. This routine does not interact smoothly with the terrain reader, and as a result, the entire affected area could not be studied with the terrain activated. The dose contours for this incident are shown below, in Figure 3.

In this simulation, the dose due to cloudshine was much more significant than for the RDW scenario. At many doses, the contributions due to groundshine and cloudshine were comparable, and at lower doses, the cloudshine dose dominated. The figure on this page shows the cloudshine dose. However, there are some problems with the cloudshine output. Figure 4 shows some cloudshine dose contours for the region within fifty kilometres of the reactor. Note that the contours often consist of isolated circles, rather than extended regions. These isolated circular regions are non-physical solutions, since the dose should drop uniformly as one moves away from the source position. Moreover,

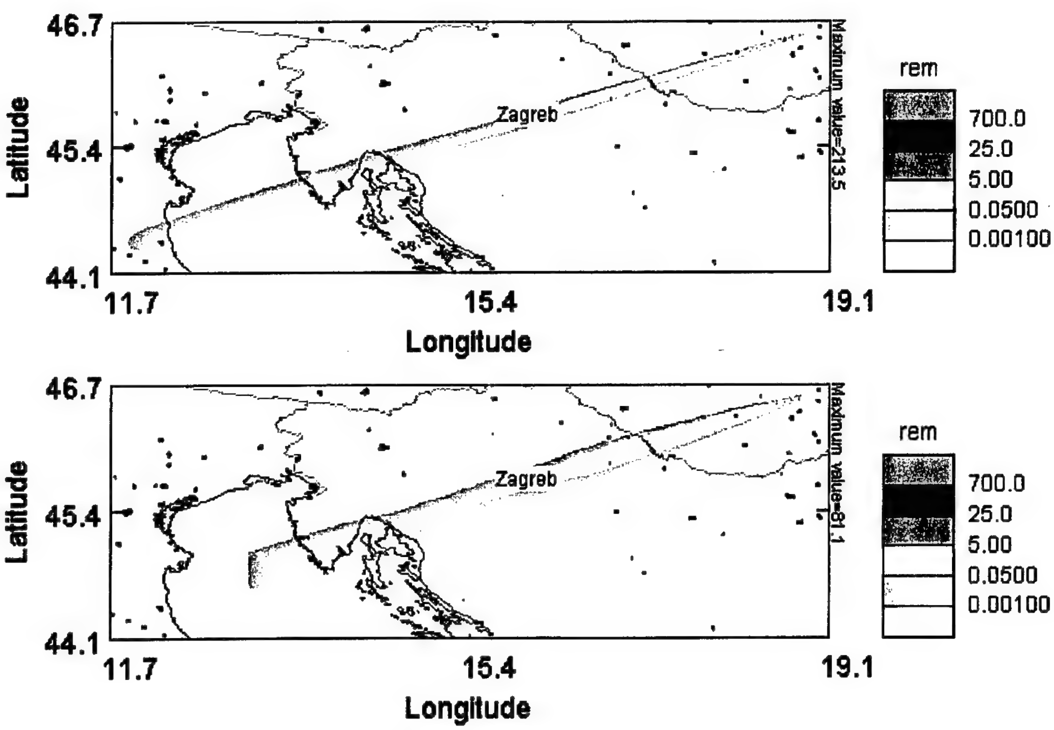

Figure 3: Dose contours for the sabotaged or damaged reactor, twenty-four hours post-incident. The upper (lower) plot shows the results of HPAC simulations ignoring (employing) terrain.

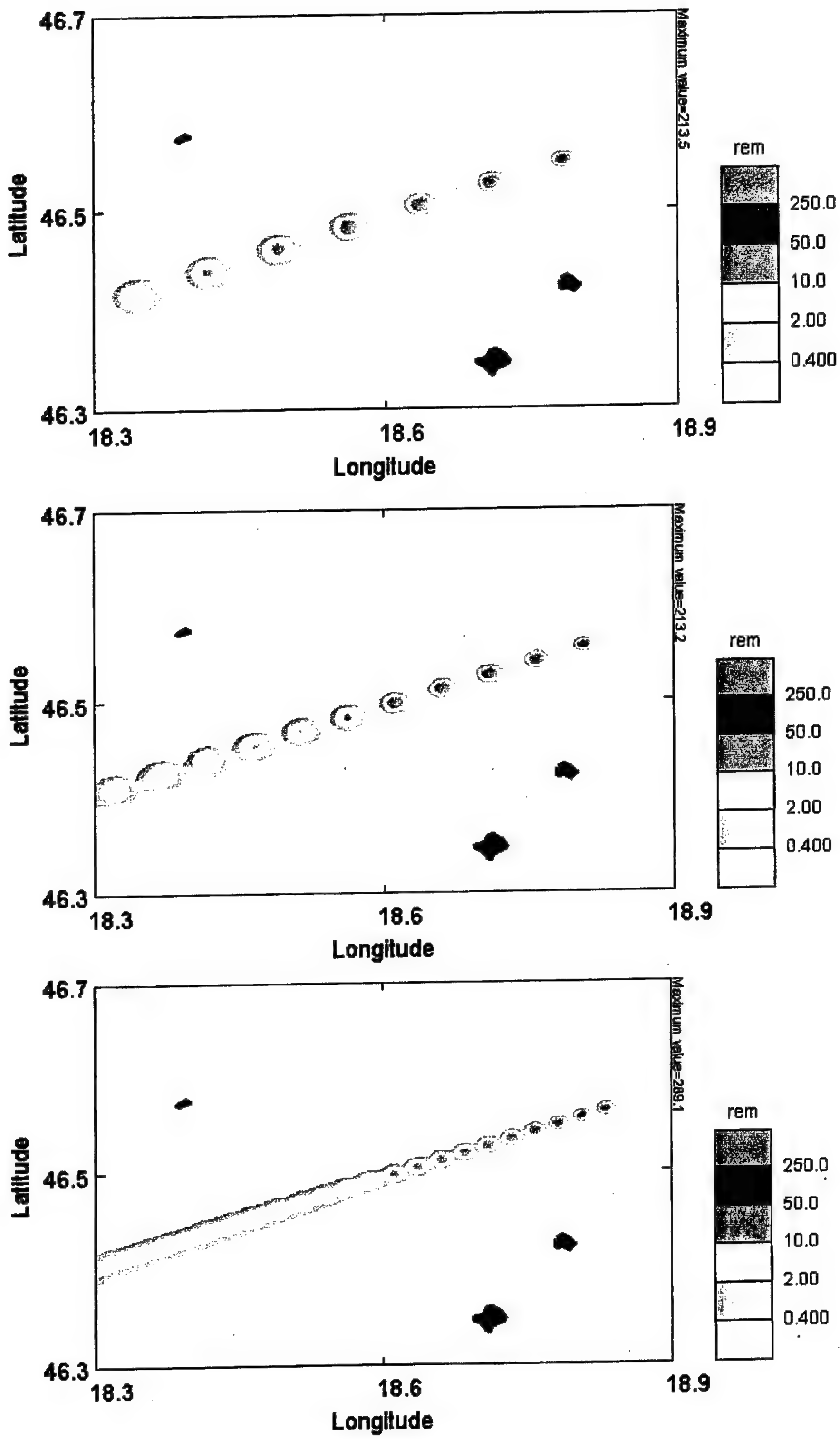

Figure 4: Doses due to cloudshine for the SDR scenario, twenty-four hours post-incident. The only difference between the three plots is the maximum time step used by HPAC during the calculation.

the air concentration (another variable that can be plotted by HPAC) shows no such patterns, and it is the air concentration from which the cloudshine is ultimately derived. In fact, this distribution looks like an artefact of the computation.

This hypothesis is backed up upon further testing. The three panels in Figure 4 differ only in the maximum time step used by HPAC during the calculation. The maximum time step is a measure of the coarseness of the computation. Although HPAC uses an adaptive algorithm to reduce the time step as it sees fit, this parameter allows the user to put a limit on how the degree to which the computer can "cut corners". In this case, as the maximum time step is reduced from fifteen minutes (upper panel) to ten minutes (middle panel) to five minutes (lower panel), the distribution becomes more realistic. Of course, reducing the maximum time step by a factor of three also increases the run time by a significant factor, and it is clear that five minutes is still too large for this time step.

Table 4 below shows the area and maximum dimensions of the areas affected by the Sabotaged or Damaged Reactor incident. The data are qualitatively different from that of the other scenarios, because in this case there is a not a large mountain range in the plume's way. As a result, the maximum downwind distances observed depend much less on the presence or absence of terrain, although the presence of terrain still tends to decrease the downwind spread of the hazard. However, the width of the hazard still tends to be much larger when terrain is included in the simulation. The obvious corollary of these two facts is that the areas of the affected regions tend to be larger when terrain is considered.

HPAC also calculates internal committed doses. These are compared with the external doses at various downwind locations in Table 5. As observed in the RDW scenario, the ratio of internal and external doses is insensitive to the presence of terrain in the simulation. However, the ratio is not constant over the range of doses observed, tending to increase with distance from the incident. This may be related to the fact that this scenario produces a significant airborne hazard that increases in importance, relative to the component deposited on the ground, as the distance from the reactor increases. As a

Table 4: Characteristics of areas contaminated by the Sabotaged or Damaged Reactor.

Dose (rad)	Area (km^2)		Maximum Downwind Distance (km)		Maximum Width (km)	
	No Terrain	Terrain	No Terrain	Terrain	No Terrain	Terrain
700	0.0189	0.0306	0.41	0.462	0.056	0.079
25	14.8	8.78	18.5	11.7	0.93	1
10	43	24.3	42.5	19.2	1.53	1.92
5	94.9	51.8	61	30	2.1	2.7
0.5	1000	1380	216	192	6.4	10.6
0.05	2700	4320	346	312	12	22
0.01	6040		542		17	
0.001	11200		586		29	

Table 5: External and internal committed doses at downwind locations.

Dose (rad)	Committed (50-year) Effective Dose Equivalent (rem)	
	No Terrain	Terrain
700	6150	6240
25	50	63
10	24	42
5	17	18
0.5	2.8	2.4
0.05	0.4	0.34
0.01	0.29	
0.001	0.01	

result, external doses will fall off more rapidly than internal doses with distance. Another possibility is that the isotopic make-up of the plume changes as one goes downwind, with the proportion of internally damaging isotopes increasing with increasing distance. This could be accomplished if the relative quantity of noble gases decreased with distance.

4 CASE STUDY: AN RDW IN IRAQ

As a further demonstration of the capabilities of this software, this section presents a final calculation. Radioactive americium-241 sources are used in conjunction with beryllium as a neutron source in oil and natural gas exploration. A ten-Curie source is not uncommon for this application. During the gulf war, there was some concern that these sources might be explosively dispersed as Iraq retreated from Kuwaiti oil fields. Because of the continuing availability of these sources, a calculation of the hazard from such an incident is in order. Indeed, DREO possesses a source similar to the one described in this section.

HPAC was used to calculate the hazard produced by the explosive dispersal of a ten-Curie source of Americium-241 by ten pounds of high explosive (the source itself is less than a pound). The incident was situated just south-west of Kuwait's capital, and the weather conditions of 30 June 1999 were used in the calculation. That is, clear conditions, winds from the north-west at twenty kilometres per hour, and a dry desert ground surface. It should be noted that this simulation includes only the effects due to the americium; it ignores the (possibly sizeable) contribution from the neutrons produced by the americium-beryllium mixture. HPAC cannot handle this latter aspect of the source.

Figure 5 shows the external doses resulting from this incident, twenty-four hours after the explosion. These rates are extremely low. Given that one can expect an external dose of 10^{-4} rads in twenty-four hours from natural radiation sources, the external doses received from this incident are insignificant. Even very close to the source, the external dose does not exceed a few times 10^{-5} rads. This is to be expected, since americium-241 emits only a few low-energy gamma rays. This, and the relatively small quantity (compared to the 1000 Ci of cobalt-60 used in the previous section) make this a very small hazard from the standpoint of external dose.

Americium-241, however, is an emitter of alpha particles, and therefore can be an extremely dangerous inhalation hazard. Figure 6 and Figure 7 show the 50-year dose equivalent to which personnel would be committed in the first twenty-four hours following the explosion. Doses of 0.1 mrem (equivalent to the external dose from natural backgrounds in one day) can be committed up to five hundred kilometres downwind of the incident, with 1 mrem doses also extending far afield. The magnified picture shows doses of 0.2 rem at approximately three kilometres downwind of the incident. This dose is the maximum allowable dose for a non-atomic radiation worker in a year. Clearly, the hazard inside this radius is significant, if not immediately life-threatening.

To re-iterate, the explosive dispersal of an americium-241 source can result in a severe radiological hazard over a distance of several kilometres. Given the availability of such sources, DND must be aware of this kind of hazard, since it offers the terrorist or rogue nation a relatively easy method of producing a significant, yet invisible, danger to unprotected personnel.

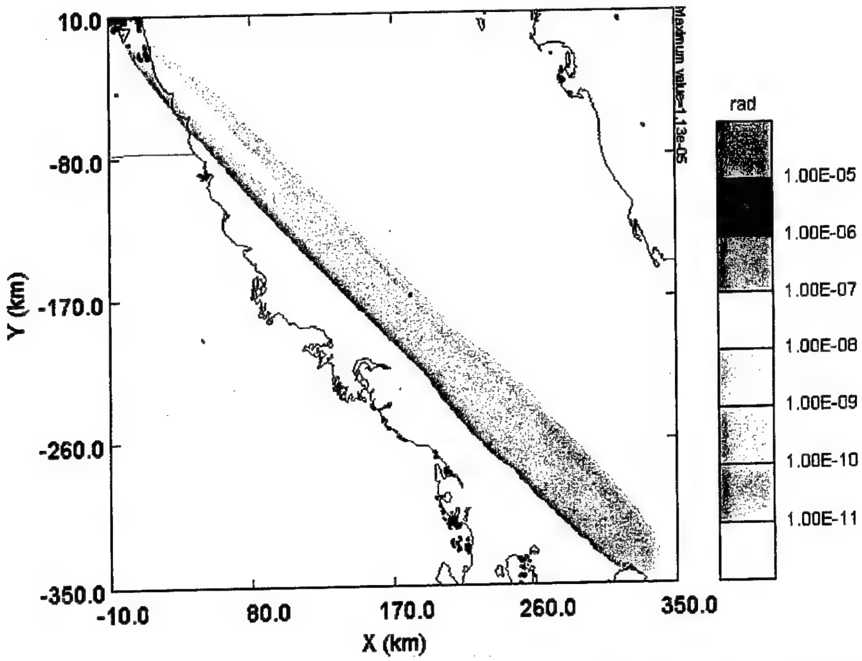

Figure 5: Total external dose received twenty-four hours following the explosive dispersal of a 10 Ci Americium-241 source. Note that these external dose rates are very small, compared to natural background rates of 0.0001 rads per day.

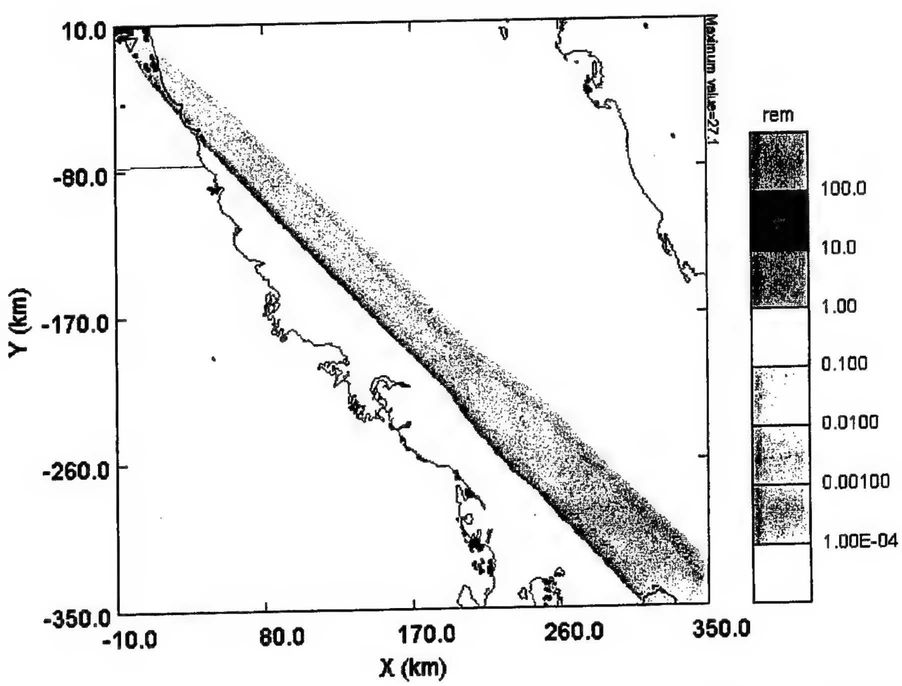

Figure 6: Committed (50-year) effective dose equivalent from inhalation, twenty-four hours following the explosive dispersal of Americium-241. Note that doses equivalent to the external background dose can be received 500 km downwind of the incident.

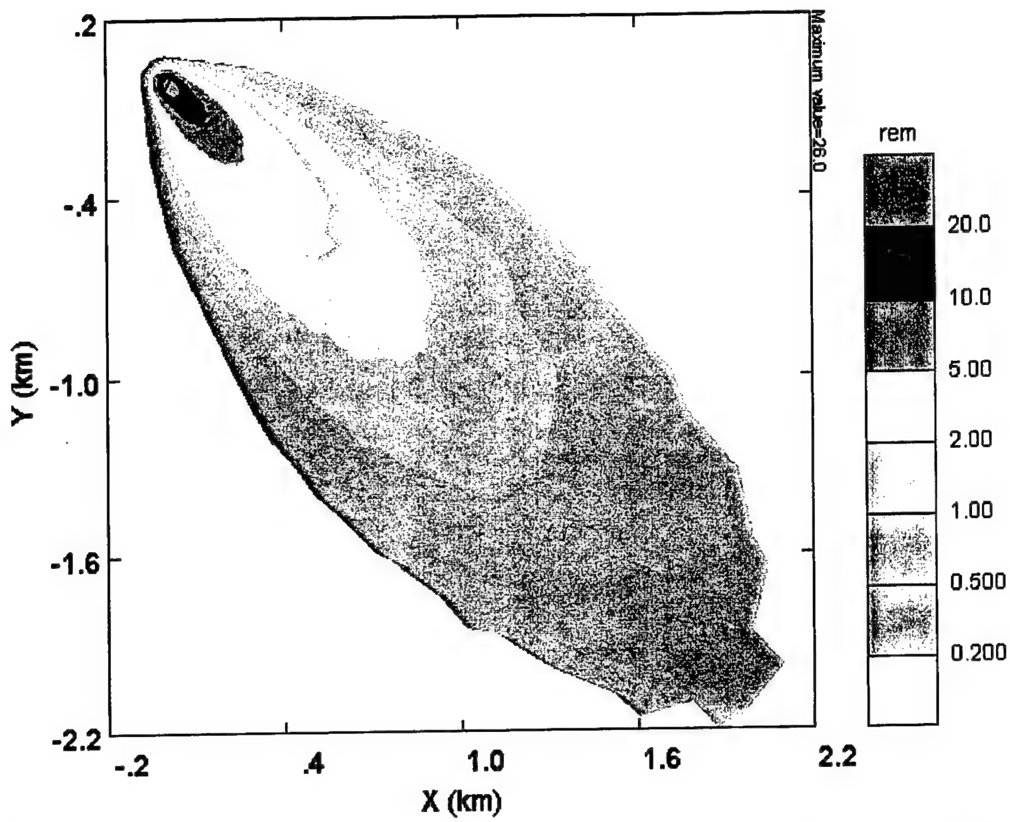

Figure 7: Same as Figure 6, but on an expanded scale. The lowest dose show, 0.2 rem, is the maximum allowable dose that a non-atomic radiation worker can receive in one year.

5 THE TOKAIMURA ACCIDENT

On the last day of the September meeting of AG-44, the news broke of the accident at the Tokaimura reprocessing facility. In approximately 30 minutes, members of the Action Group were able produce a first approximation to the hazard areas around Tokaimura, with information on the incident and on current meteorological conditions downloaded from the Internet. Figure 8 below shows the results of this calculation. This report will not go into detail on how this incident was simulated; this will be the subject of a future report. This example is shown purely to demonstrate how quickly and with how little information such a calculation can be done.

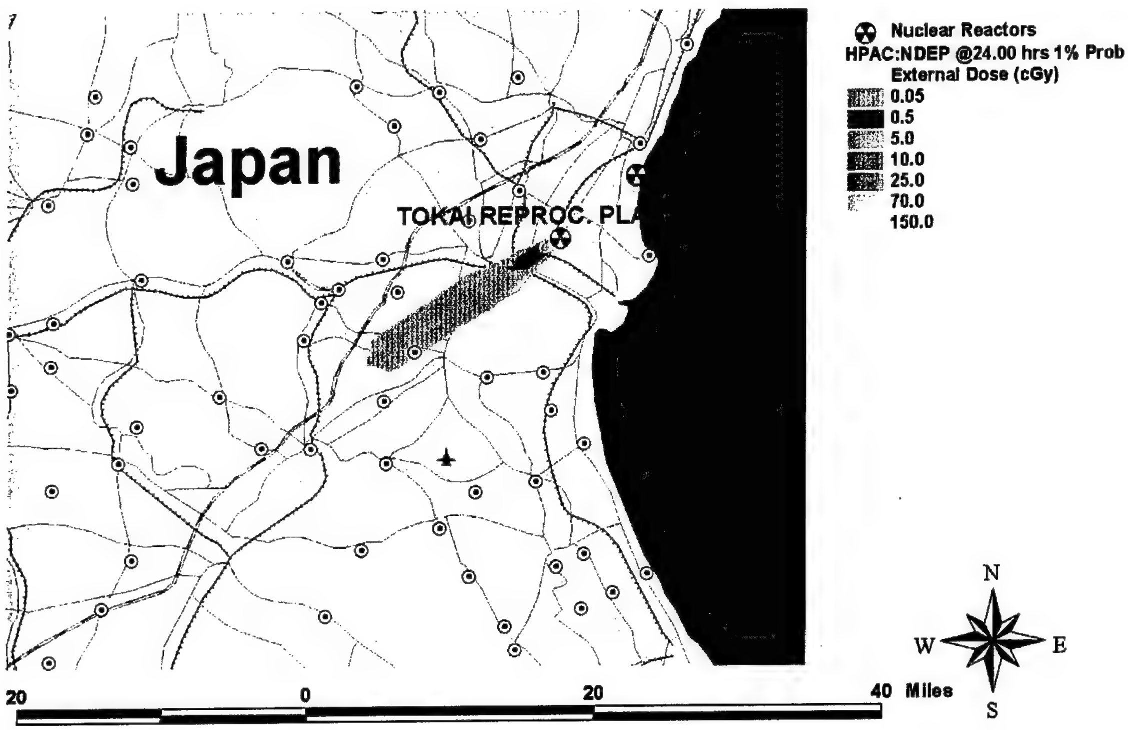

Figure 8: Predicted external dose contours, 24 hours after the Tokaimura release. Contours are given with 99% confidence.

6 CONCLUSIONS AND RECOMMENDATIONS

The HPAC code is a very sophisticated piece of software that permits simulations of the most commonly considered radiological hazard scenarios. Developments in the software, and increases in computing power, have now made this kind of simulation accessible to even non-scientific users. This greatly increases the possible applications of the software.

Science Applications International Corporation (SAIC) is developing, under contract to the US Department of Defense, the Consequence Assessment Tool Set (CATS) [3]. This software takes input from HPAC, and allows the user to use the hazard assessment to calculate such quantities as the population at risk, or the number of affected hospitals. As HPAC and CATS are further refined, they will surely become easier to use, perhaps overcoming the problems with data output encountered during this work. The Radiation Effects Group at DREO will keep abreast of developments in these pieces of software.

The CATS software is particularly interesting because it has found use elsewhere in DND. It has, for example, been used in the development of the CIBADS Hazard Assessment Modelling System (CHAMS) [4] software at DRES. Progress at DRES in this area should be monitored so that possible synergies between Biochemical and Radiological hazard assessment can be exploited.

The CF Nuclear Detection, Identification, and Dosimetry Project, G2199 [5], should also keep aware of advances in these software packages. Their ease of use makes them amenable to the production of scenarios for CF training in the handling of radiological hazards. As the training requirements of this project become further defined, HPAC or another package like it may be considered for acquisition.

7 REFERENCES

[1] Hazard Prediction and Assessment Capability (HPAC), version 3.0, produced and distributed by the Defense Special Weapons Agency, 1997.

[2] R. I. Sykes, "PC-SCIPUFF Version 0.2 Technical Documentation", Apr 95.

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The dispersal of radioactive materials in a number of military scenarios has been modelled computationally. This work is part of an international intercomparison of computational capabilities under the auspices of Action Group 44 of The Technical Co-operation Program. The results presented herein were obtained with the Hazard Prediction and Assessment Capability (HPAC), designed by the US Defense Threat Reduction Agency (DTRA). This sophisticated software can be used to quickly determine the extent of radiological hazard areas, requiring a relatively small quantity of information from the user. The potential of this software for applications such as pre-deployment preparation, or even pseudo-real-time hazard prediction with input from hand-held radiation detection equipment must be recognised.

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